

Lean Manufacturing and the Defense Industry Lessons for Cost Analysts

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Since the end of the Cold War, the Department of Defense (DoD) has launched a number of initiatives whose common objective has been to reduce the costs of weapon systems that are planned, under development, or in production. Largely in response to these measures, U.S. defense firms have in recent years begun to embrace lean manufacturing, a broad collection of principles and practices whose aim is to refashion the production process in a manner that includes the elimination of waste, the removal of inventory buffers, and a focus on quality. To date, however, few studies have been undertaken to determine the extent to which government cost-estimating tools should be appropriately adjusted to reflect the growing use of such practices within the military aircraft industry.

In *Military Airframe Acquisition Costs: The Effects of Lean Manufacturing*, RAND authors Cynthia R. Cook and John C. Graser thoroughly assess U.S. military aircraft manufacturers' use of lean practices with the goal of determining to what extent, if any, the industry's adoption of such practices should be incorporated into government cost-estimating models. After briefly tracing the history of lean manufacturing, the authors describe in detail the manner in which lean principles have informed each critical phase of military aircraft production. Drawing from a comprehensive survey of the industry, they then outline the degree to which manufacturers have adopted lean practices as well as the savings claims from having done so. Although they conclude that it would be premature for the DoD to adjust its cost-estimating tools to reflect projected savings from lean manufacturing, the authors delineate the manner in which contractors' claimed savings could influence future aircraft cost estimates.

LEAN MANUFACTURING PRINCIPLES: AN INTRODUCTION

Lean manufacturing traces its origins to Toyota's production model, whose tightly coupled and meticulously coordinated manufacturing system was designed to drive closer linkages between all functions within the organization. Central to Toyota's manufacturing philosophy was the maintenance of an extremely low inventory—a practice that in Toyota's view forced attention on eliminating potential problems at their source.

Lean manufacturing has grown to encompass a host of other elements, salient among which is its value-stream focus. This overarching principle holds that manufacturers must first understand virtually every step in a product's evolution—that is to say, its "value stream"—if they seek to fabricate that product more efficiently. Armed with this knowledge, manufacturers must then search for bottlenecks that may impede the production process and, having done so, must incorporate new tools and techniques into that process as part of a continuous effort to cut costs and improve quality.

Although lean manufacturing holds the potential to significantly reduce costs, it has also been associated with a spectrum of challenges. By its very nature, for example, the lean process hinges on meticulous coordination between all of an organization's activities and functions. The implementation of lean practices can thus be a difficult and time-consuming endeavor.

Additional problems have been associated with the use of lean processes in an aerospace context. In low-

volume industries such as aerospace, for example, parts that may become obsolete must often be purchased at the outset of production—a practice that runs counter to the lean principle of maintaining minimal inventory. In addition, the aerospace industry's unique relationship with the Department of Defense—its major and often its only customer—has posed problems of its own. The fact that DoD typically establishes the price it pays based on manufacturers' costs may serve as a disincentive to the implementation of productivity improvements. Nonetheless, the need for efficiency in aircraft manufacture can only increase as post-Cold War military budgets continue to decline.

LEAN PRACTICES IN THE MILITARY AIRCRAFT INDUSTRY

Although lean manufacturing is guided by a number of overriding principles, the manner in which these principles are put into practice varies according to function.

Engineering. In many ways, the design engineering function lays the groundwork for lean manufacturing by integrating the perspectives of all relevant participants at the outset of the design process. This integration takes place primarily through the use of integrated product teams (IPTs).

The military aircraft industry has recently made extensive use of IPTs in its efforts to ensure that all key stakeholders in the production process, both internal and external, are given a voice in aircraft design. Despite this widespread use, however, many contractors interviewed questioned the cost-effectiveness of IPTs. Several respondents, for example, expressed the opinion that IPTs involved more initial investment than did traditional design arrangements, primarily because of the costs of coordinating the greater number of people involved in the design process. Moreover, no data were yet available to support the contention that this initial investment had yielded lower manufacturing costs.

Yet another innovation that has dramatically altered aircraft manufacture is computer-aided design (CAD). By obviating the need for cumbersome mockups and schematics, CAD has greatly facilitated aircraft production, allowing up-front attention to be paid to quality, manufacturability, and cost. As with IPTs, however, not enough aircraft units have been produced by this means to buttress claims of long-term savings. Indeed, preliminary evidence indicates that engineers are not necessarily using CAD tools to design aircraft more quickly but may instead be harnessing these and other technologies to produce better designs in the same amount of time.

Tooling. A number of tooling advances also hold promise of contributing to lean manufacturing. Flexible

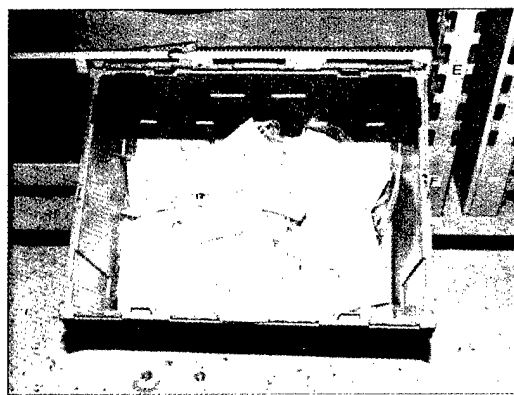
tools, for example, can be used to fabricate or assemble multiple parts rather than being dedicated to a particular part, thereby removing bottlenecks from the production process. Again, however, scant data were available to corroborate the claim that any cost or time savings had yet resulted from the use of such tools.

Manufacturing. Lean manufacturing exerts its influence on the factory floor in a number of ways. As with conventional productivity improvements, lean manufacturing practices share an emphasis on cutting costs and minimizing waste. Unlike traditional cost-saving measures, however, such practices advocate that attention be paid both to value-added work, in which a product is machined in accordance with its intended design, and to non-value-added processes, in which a product awaits work or undergoes reconfiguration.

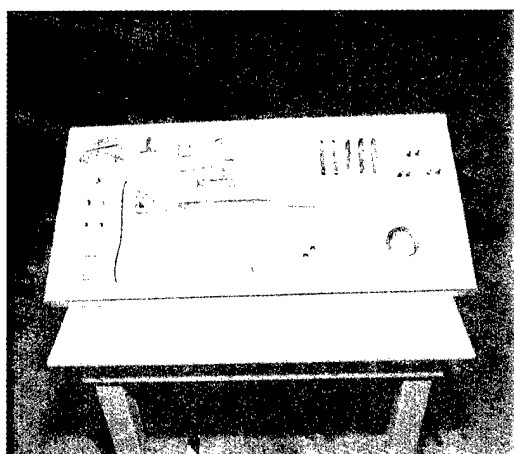
Central to the implementation of lean manufacturing is pull production, a practice that calls for the manufacturing process to begin only when an order from a customer has been received. This approach helps reduce finished-goods inventories while also eliminating waste. Similarly, the lean principle of cellular production focuses on a part or product rather than on a process such as cutting, grinding, or drilling. Within a "cell," all the machines that work on a particular part are in sequence so that, as soon as one process is finished, the part can be moved to the next operation. Keeping the product moving reduces the amount of inventory stacked up and waiting to be worked on, and it enables earlier identification of quality problems as well. Lean manufacturing also advocates that a range of procedures be adopted on the factory floor, including the use of "shadowboxes" that organize parts or tools in such a way as to make it immediately evident when an item is missing or misplaced (see Figure 1).

All the prime contractors that participated in this study reported some experience in the use of lean manufacturing on the factory floor, and many contended that these early efforts had already yielded considerable savings. In a sample of 20 pilot programs, for example, manufacturers reported that the direct labor hours required to produce parts had declined between 5 and 81 percent following the institution of lean practices. Similarly, it was claimed that lean procedures had diminished the cycle time required to produce parts by 13 to 93 percent. Such results offer preliminary evidence that lean principles have the potential to reduce aircraft manufacturing costs. At the same time, however, it is not yet clear whether the savings achieved in these limited efforts can be extrapolated to the implementation of lean principles throughout a manufacturing facility.

Quality Control. The focus on quality is one of the hallmarks of the lean production system. Unlike tradition-



Parts presentation kit before lean manufacturing



Parts presentation shadowbox after lean manufacturing

SOURCE: Lockheed Martin.

Figure 1

al production methods, however, lean manufacturing seeks to ensure that quality is built in rather than inspected in. Put more precisely, the lean philosophy focuses on finding the root cause of a problem, thereby remedying that problem at its source.

Companies surveyed described quality control policies that had been implemented as part of the lean manufacturing effort. Several firms, for example, claimed that their operator self-inspection programs had resulted in a substantial decrease in the number of quality control personnel. Yet because the costs of quality control are often estimated as a percentage of factory labor or manufacturing costs, the effect of lean implementation on the quality function cannot yet be gauged with any degree of accuracy.

Purchasing. Purchased materials and parts make up a significant portion of the cost of the typical military aircraft, usually comprising some 50 to 70 percent of the cost value stream. Organizations that have adopted lean manufacturing thus attempt to maximize the quality and

reduce the costs of purchased parts largely by forging long-term partnerships with key suppliers.

The authors found evidence that all major aerospace companies had programs designed to reduce costs through proactive supplier management. And while respondents' levels of implementation varied, prime contractors interviewed all reported significant success in improving the quality of their purchases. Lean supplier management may thus hold real potential to generate savings, both from reduced material costs and from the production of higher-quality goods. Such savings, however, are contingent on the consistent implementation of lean practices.

Overhead and General and Administrative Costs.

Although much of the attention that has been paid to productivity improvement has focused on actual production, indirect costs such as overhead and general and administrative (G&A) expenses can also be significant drivers of weapon system costs. Accordingly, a number of lean manufacturing initiatives have been designed to help contain such costs. However, respondents' efforts to reduce overhead and G&A were limited in scope and await systematization before significant savings can be realized.

CONCLUSION: PREMATURE FOR DoD TO ADJUST COST-ESTIMATING MODELS TO ACCOUNT FOR LEAN PRACTICES

The results of this study clearly indicate that the integration of lean principles into military aircraft production remains in a state of flux. To be sure, nearly all manufacturers surveyed as part of this research had either implemented lean pilot projects or expressed their intention to do so. Moreover, all manufacturers who had initiated such projects reported that savings had already been derived from their efforts. At the time of this research, however, none of the manufacturers surveyed had yet implemented lean manufacturing practices on a broader scale, either from the beginning to the end of the value stream or within the factory as a whole. Hence, it was difficult to assess the accuracy of any of the claims made regarding the effects of lean manufacturing on overall aircraft costs.

Given the dearth of systematic data on the savings that have been achieved from lean manufacturing, the bottom-line finding of this report is that no macro adjustments to historical cost-estimating methodologies can yet be made. This is not to say that aircraft manufacturers are not trying to reduce weapon system costs through the application of lean principles; rather, it suggests that factoring these savings into the cost estimates of aircraft systems must await the collection of more comprehensive data. In the interim, it is suggested that individual lean initiatives be analyzed and baseline cost estimates discretely adjusted on a case-by-case basis.

This research brief describes work done for RAND's Project AIR FORCE; it is documented in Military Airframe Acquisition Costs: The Effects of Lean Manufacturing by Cynthia R. Cook and John C. Graser, MR-1325-AF, 2001, 180 pp., ISBN: 0-8330-3023-X, available from RAND Distribution Services (Telephone: 310-451-7002; toll free 877-584-8642; FAX: 310-451-6915; or email: order@rand.org). Abstracts of all RAND documents may be viewed on the World Wide Web (www.rand.org). Publications are distributed to the trade by NBN. RAND® is a registered trademark. RAND is a nonprofit institution that helps improve policy and decisionmaking through research and analysis; its publications do not necessarily reflect the opinions or policies of its research sponsors.

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